Impacts of Urbanization vs. Global Warming in Southern California Coasts

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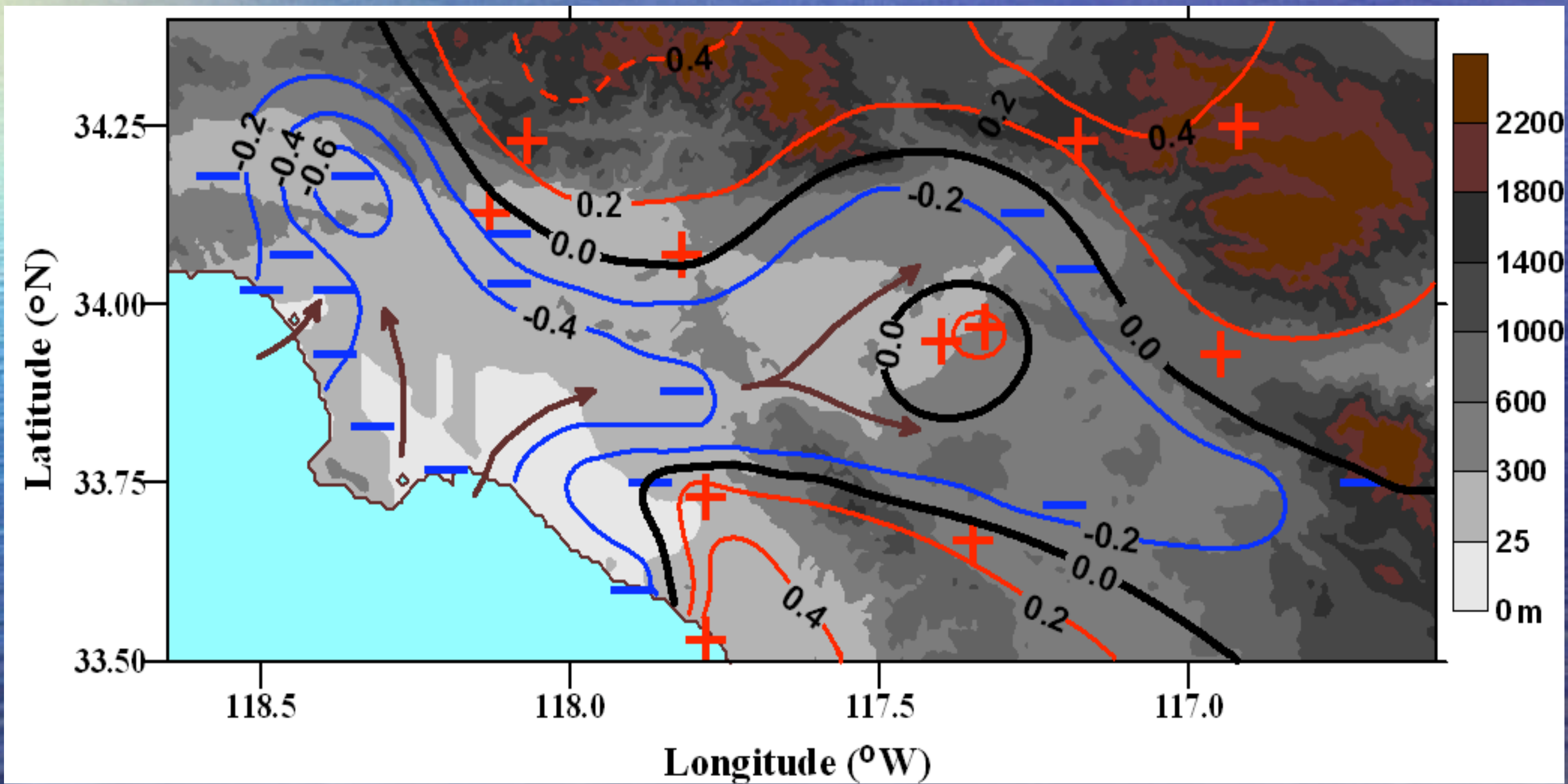
Outline

1. Background and Hypothesis
2. Simulation Details
    - Grid Configuration
    - Land Use input
    - Anthropogenic heating
3. Results & Validation
4. Conclusion

Background: Lebassi et al. (1 July 2009), J. of Climate

Observed 1970-2005 CA JJA max-Temp (^{0}C/decade) trends in SFBA & SoCAB (below) showed concurrent

> low-elevation coastal-cooling & > inland-warming



Current Hypothesis

INCREASED INLAND WARMING →
INCREASED HORIZONTAL T- GRADIENTS (COAST TO INLAND)→
INCREASED SEA BREEZE: FREQUENCY, INTENSITY, PENETRATION, &/OR DURATION →
COASTAL REGIONS SHOULD THUS EXPERIENCE COOLING TEMPS DURING SUMMER DAYTIME PERIODS

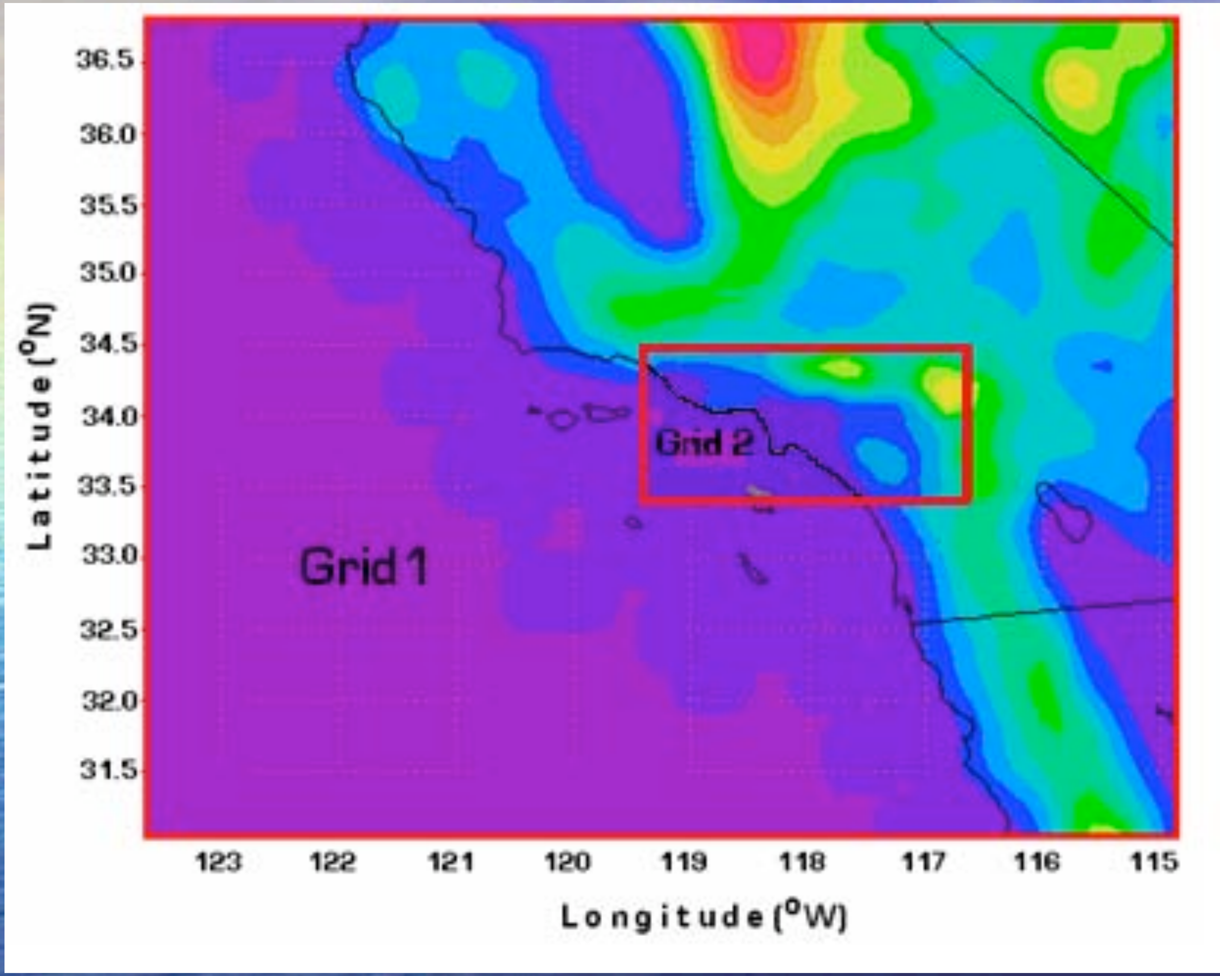
Methodology

- Current goal: separate out effects of urbanization & LULC changes on observed Lebassi et al. temp-trends and on sea breeze flow patterns by use of numerical simulations
- Regional Atmospheric Modeling System (RAMS) model
  - Runs 1 vs. 2:
    - Research question: Effects of urbanization?
    - Both runs: JJA 2002 climate
    - Run 1: current urban LULC (NOAA 2002, at 30 m resolution
    - Run 2: pre-urban LULC (all urban turned to dominant class, i.e., scrubland)
  - Runs 1 vs. 3:
    - Research question: Effects of global climate change?
    - Run 3: uses
      - Run 1 (Current) LULC
      - Past JJA 1970 climate (only for August 1-10, 2002 for now)

Simulation Details

- Model initialized:
  - Runs 1 & 2 (JJA): 0000 UTC, 1 June 2002
  - Run 3 (10 day): 0000 UTC, 1 August 2002
- 12 h spin up
- Large scale BCs: every 12 h, from gridded NCEP global-model output
- 4DDA in Grids 1 & 2:
  - Newtonian relaxation (nudging)
  - with time scale of 6-h

Grid Configuration for SoCAB simulations



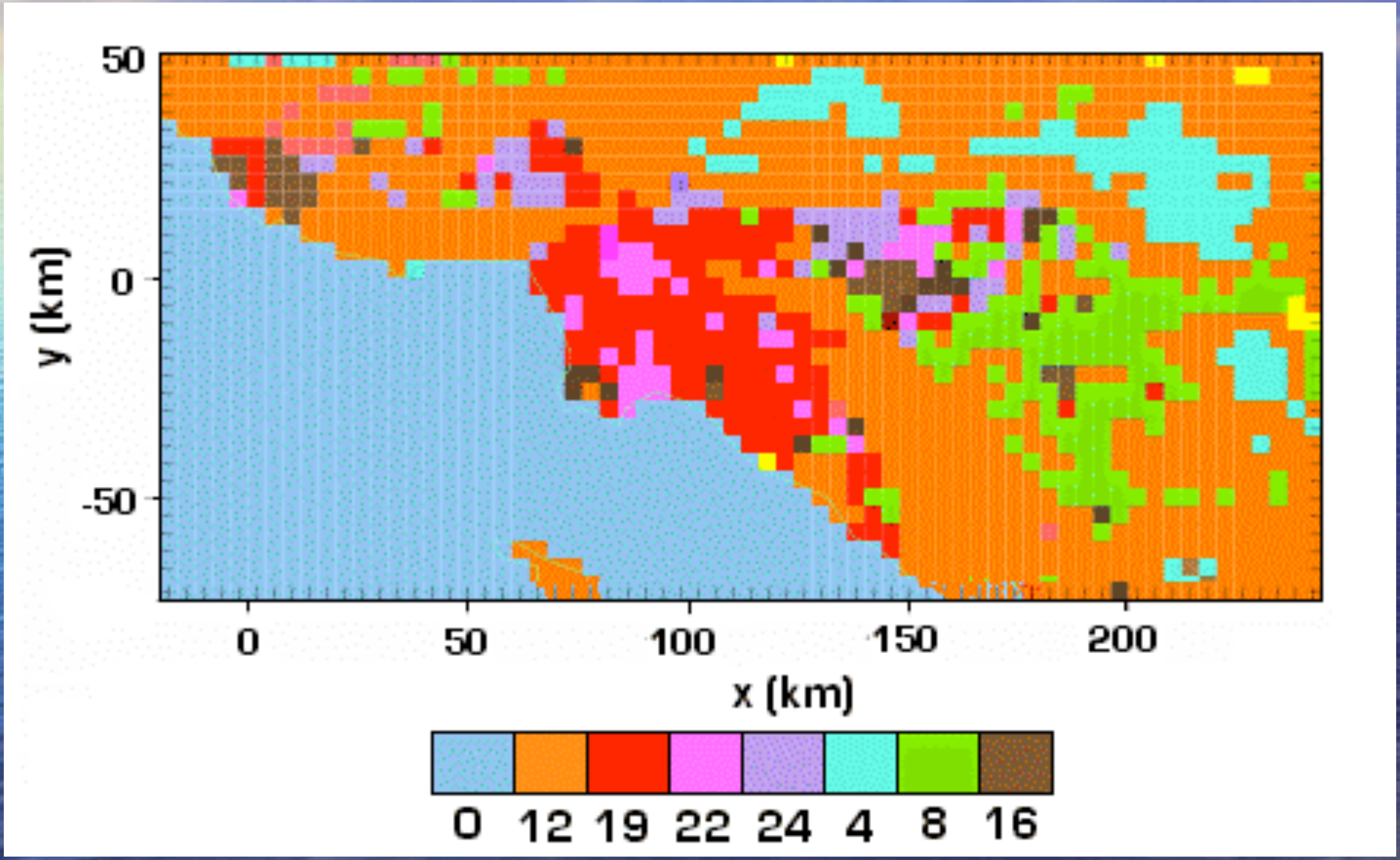
Horizontal Grid

➢Arakawa- C staggered grid

> 2 nested grids
- Grid 1: 20 km resolution
- Grid 2: 4 km resolution

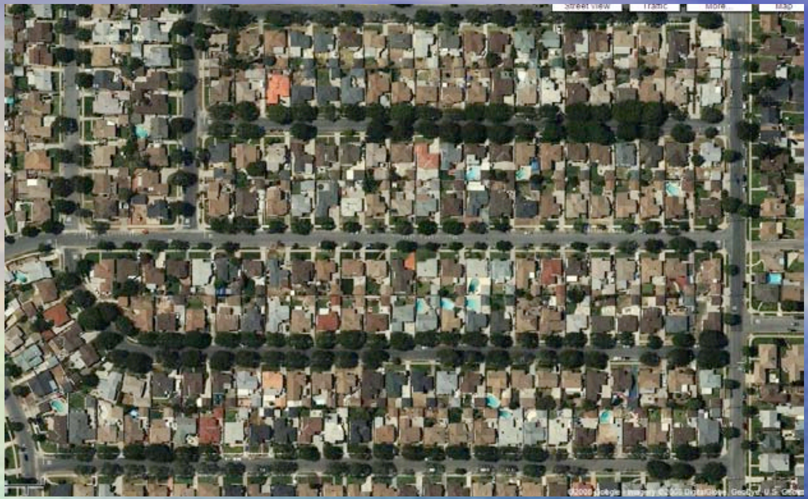
Grid 2 (4 km) LULC-classes: present case (2002)

- Input: 30 m NOAA LULC mapped into Leaf-3 RAMS classification
- Output: dominant class, with parameter values as weighed averages
- Urban Classes 19 (red) , 22 (pink), & 24 (grey)



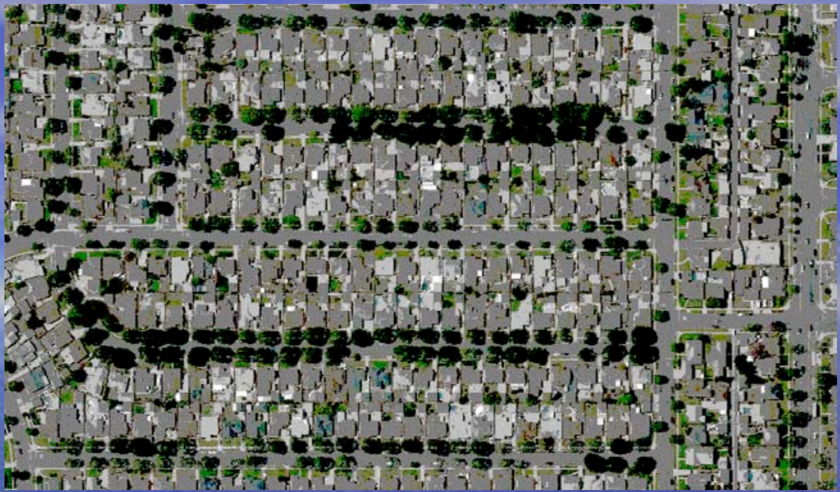
New Tech: determination of urban Veg, Rooftop, & Street fractions

(a)



Initial visible Google map for typical urban class 19

(b)



Resulting 16 color visible image: 32% is veg & 68% is roof + street

(c)

> Resulting 2 color visible image: building are white (52%): & vegetation + streets are black (48%) ➔
> Thus (48-32%=) 16% are streets

Methodology:

- Start w/ **visible Google map** for typical urban area (map-a)
- Change map-a to 16-color image (map-b) & count fraction of green pixels (32%)
- Change map-a to 2-color image (map-c)
  - > where white fraction is rooftop & black fraction is thus veg + streets
  - > Street fraction is thus black fraction minus green fraction (from map-b)
- Only veg fractions can be input into current RAMS lookup table

Anthropogenic Heat Fluxes for current SoCAB Simulations

- TEB model
  - not used in current simulations,
  - as it only uses constant emitted anthropogenic heat fluxes due to traffic and industrial activities
- Sailor and Lu (2004)
  - used in current simulations, as it
  - is based on "top-down" approach (next slide)
  - uses realistic diurnal, weekly, & seasonal emitted anthropogenic emission-cycles (next slide)

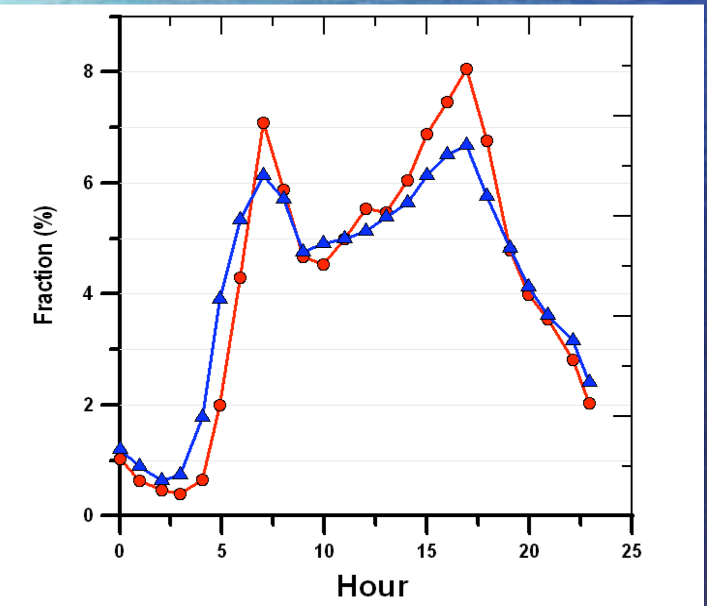
Anthropogenic heat flux: **Sailor and Lu (2004)**

$$Q_F = Q_{Vehicle} + Q_{Building} + Q_{Metabolism}$$

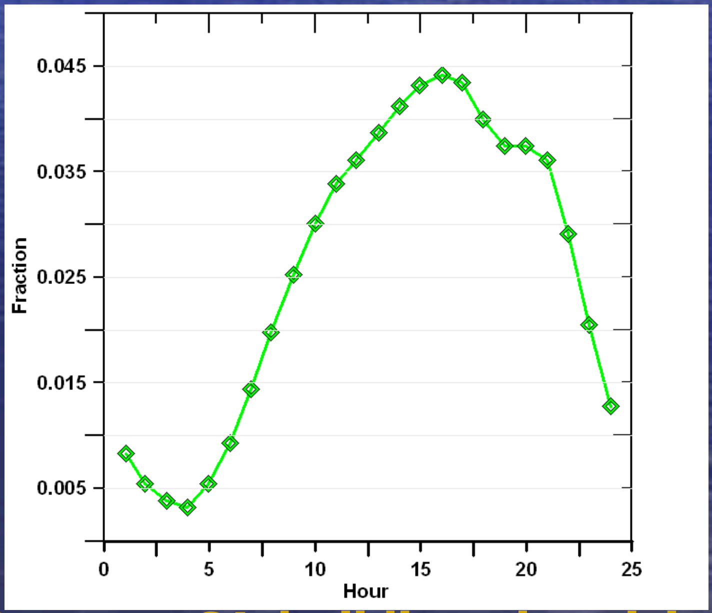
$$Q_{Vehicle} = \rho_{pop}(t) \cdot F_V(t) \cdot E_V \cdot DVD$$

Where:

- $\rho_{pop}(t)$ Population density [person/km^2] : from US census
- $F_V(t)$ Non-dimensional vehicle traffic-profile (lower right slide)
- E_V Vehicle energy-used [W/km]: from DOT
- DVD Distance traveled per person [km]: from DOT

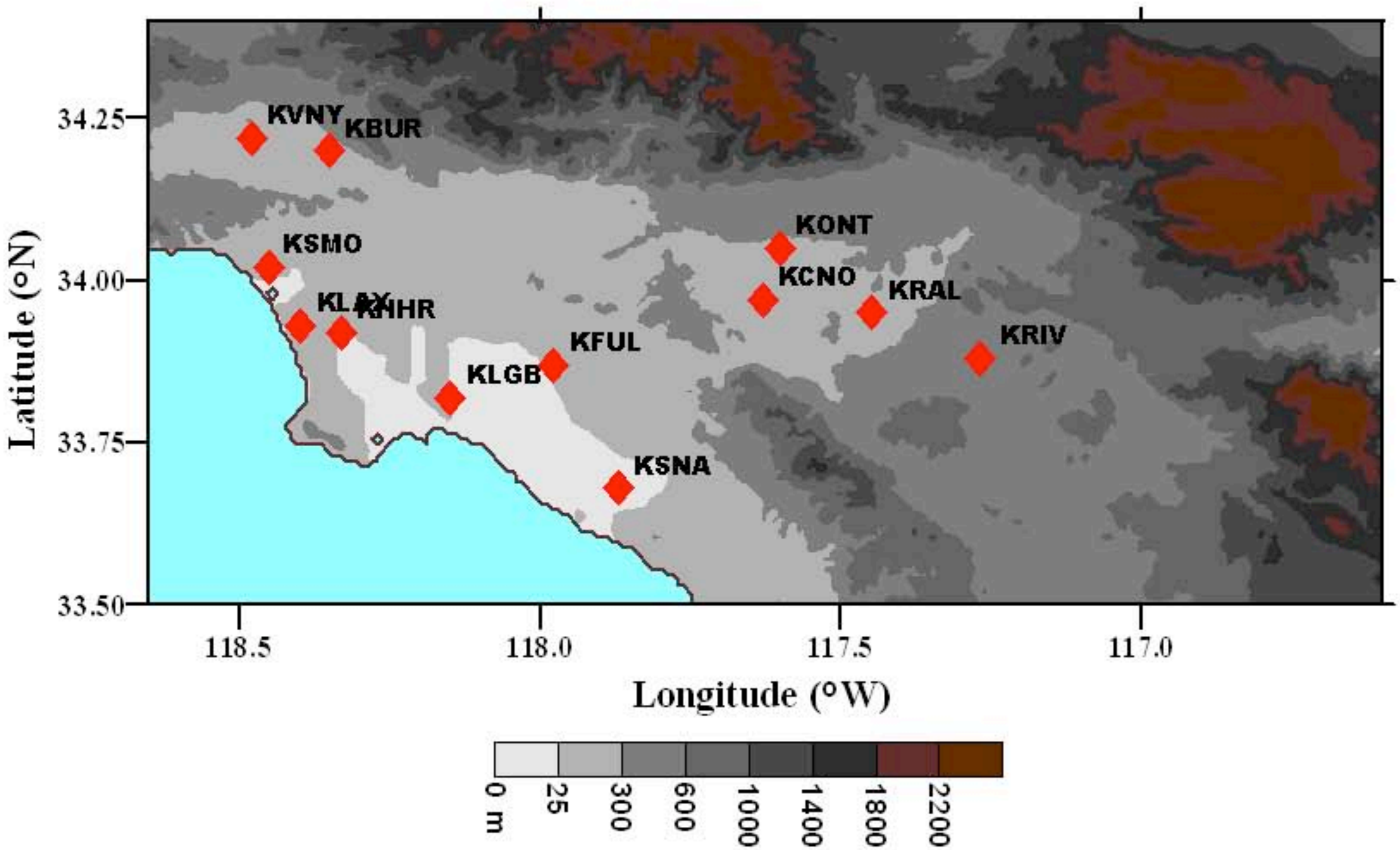


Traffic-profile (%): red is US & blue is LA



Summer CA-building electricity fraction (Sailor and Lu, 2004)

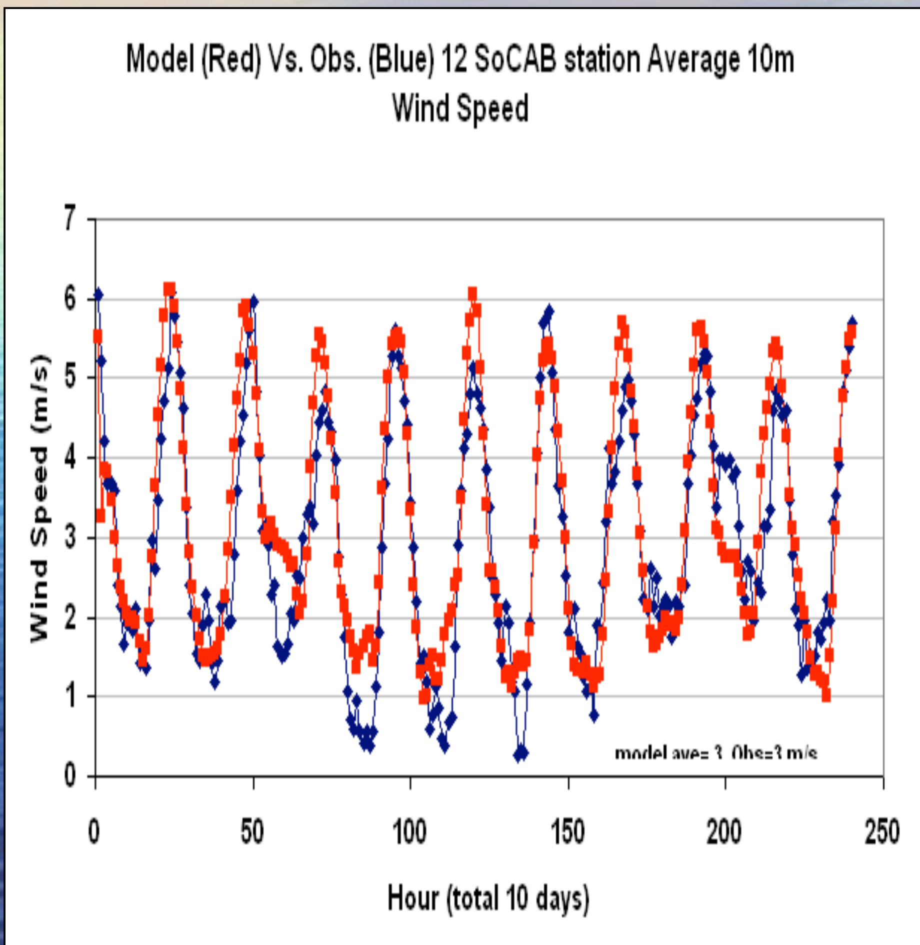
SoCAB Validation: 12 METAR Stations



Model Validation with Run-1 (current met & LU) output: 10-day averages for 12 SoCAB sites

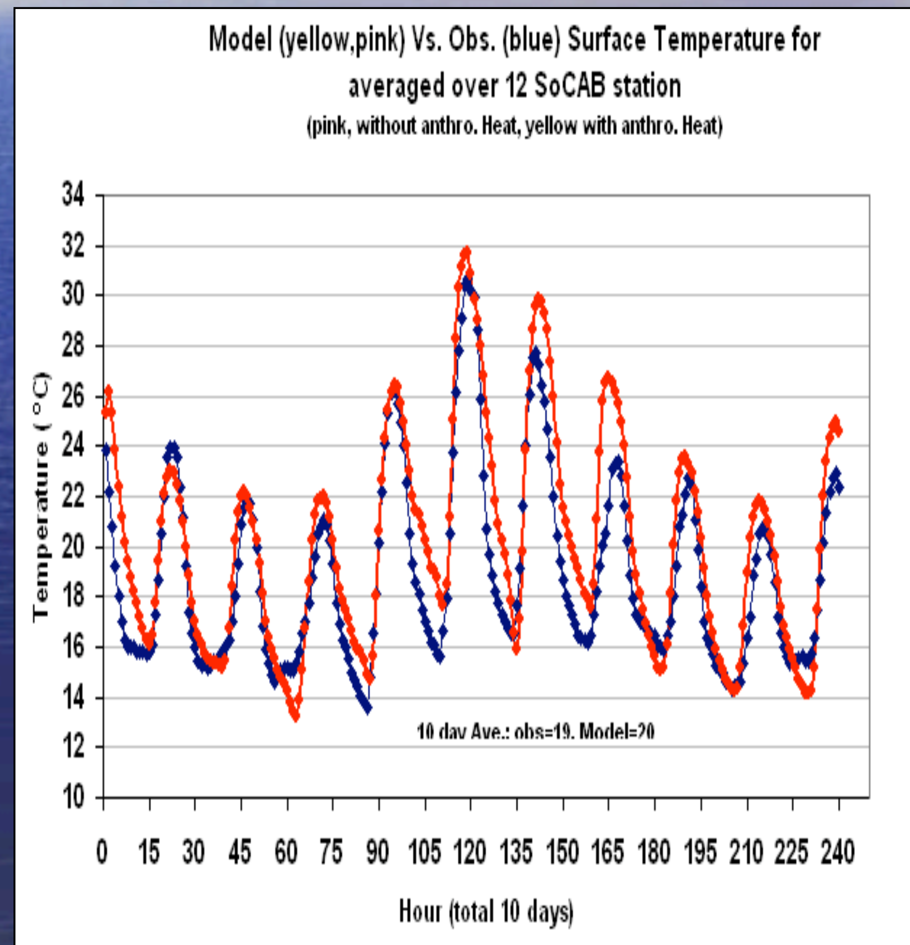
wind speed:

Model =3 m/s vs. obs = 3 m/s

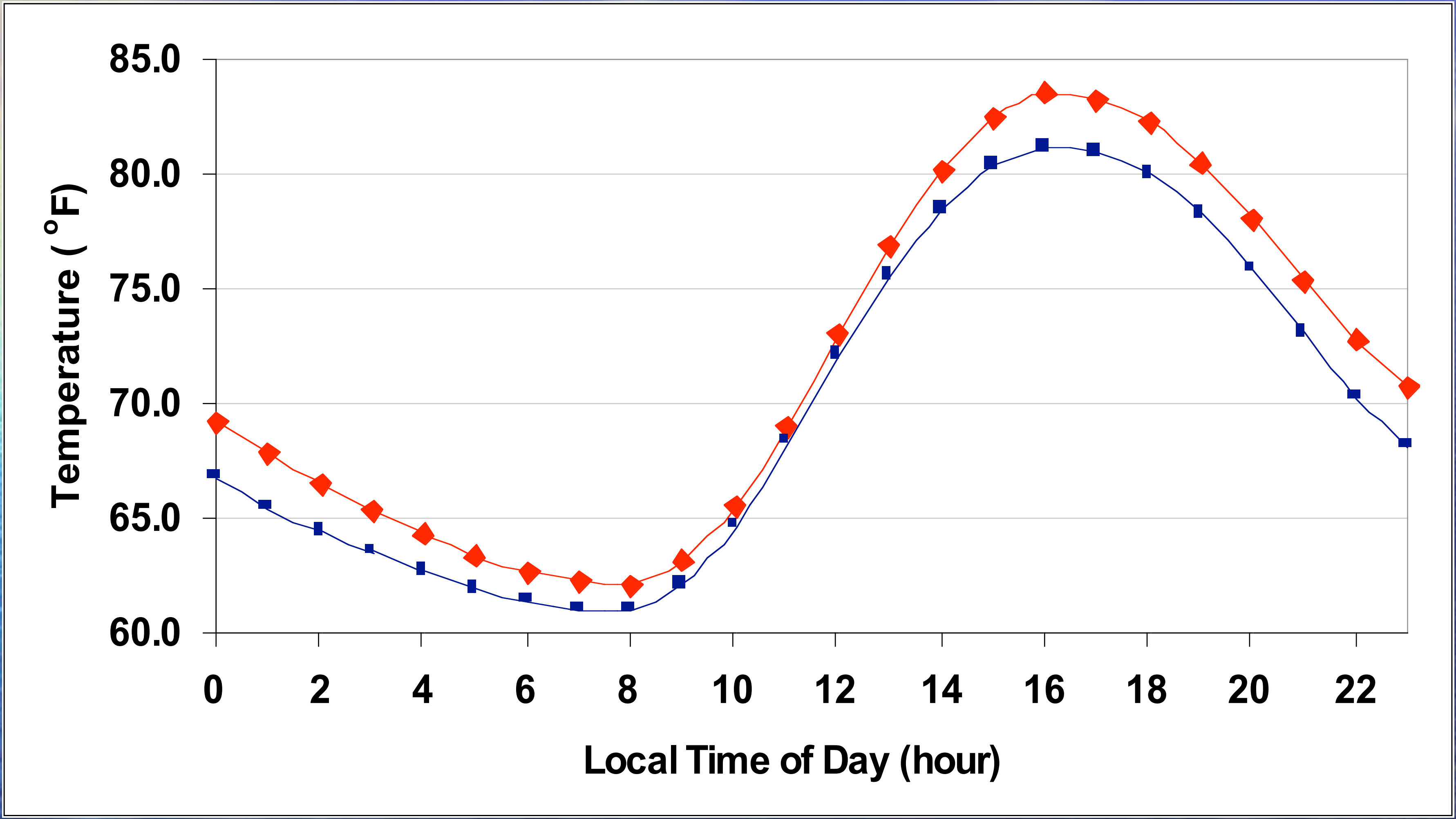


temp:

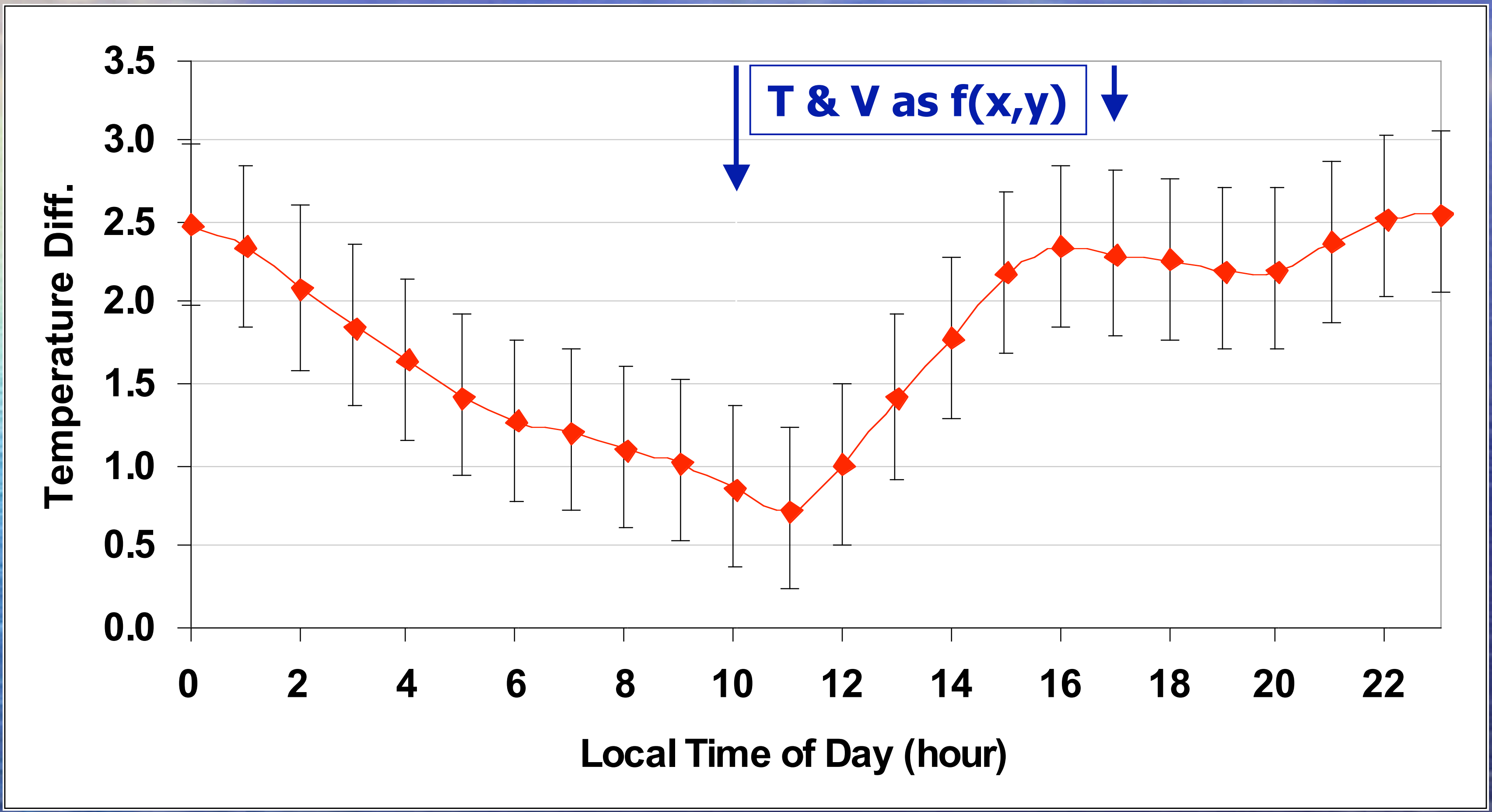
Model = 20^{o}C vs. obs = 19^{o}C



July Average Temperature at Urban (red) & Rural (blue)



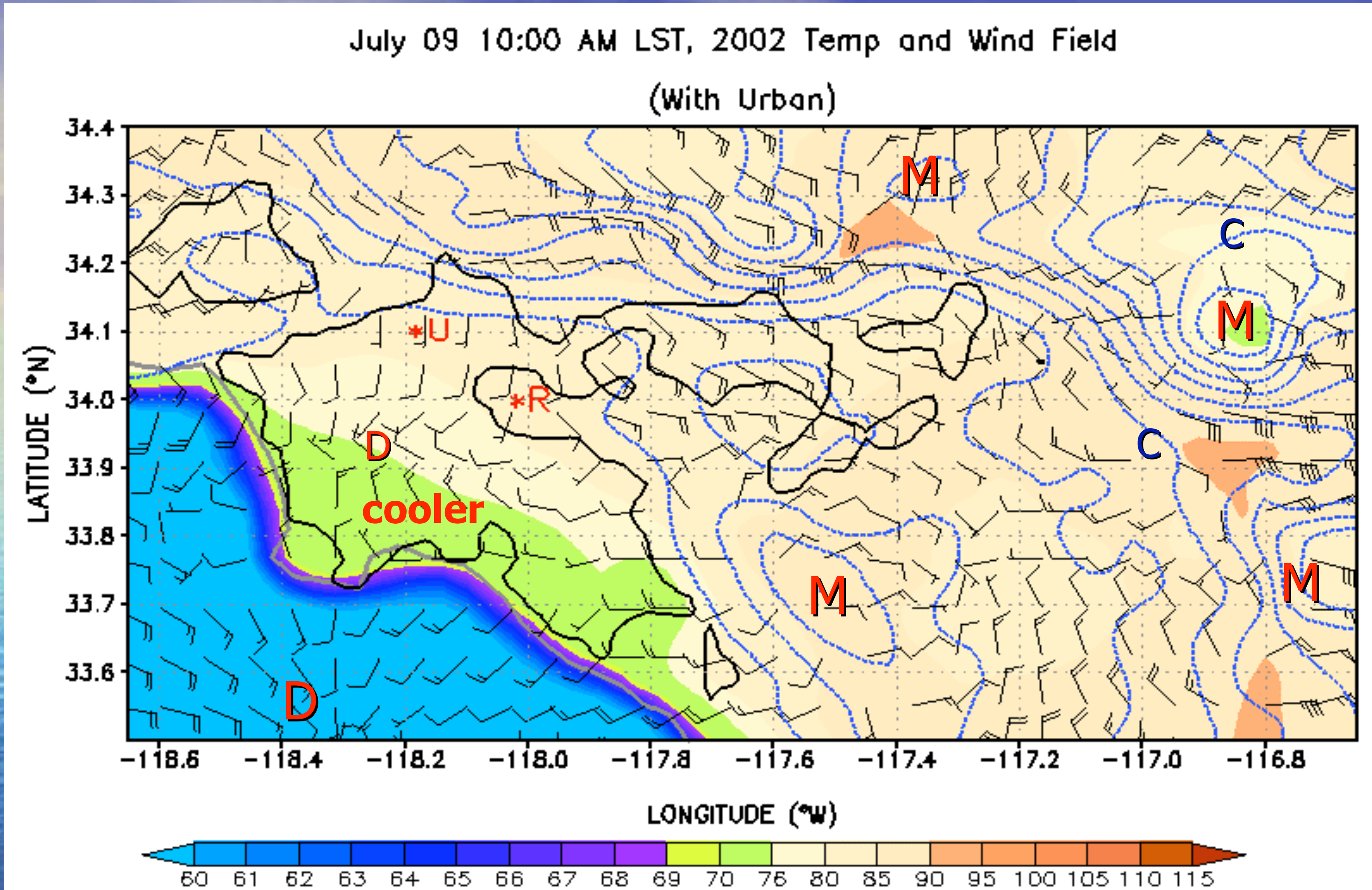
24 hr UHI (t) ± 1 σ



T & V as f(x,y)
Temperature Diff.
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
14
16
18
20
22
Local Time of Day (hour)

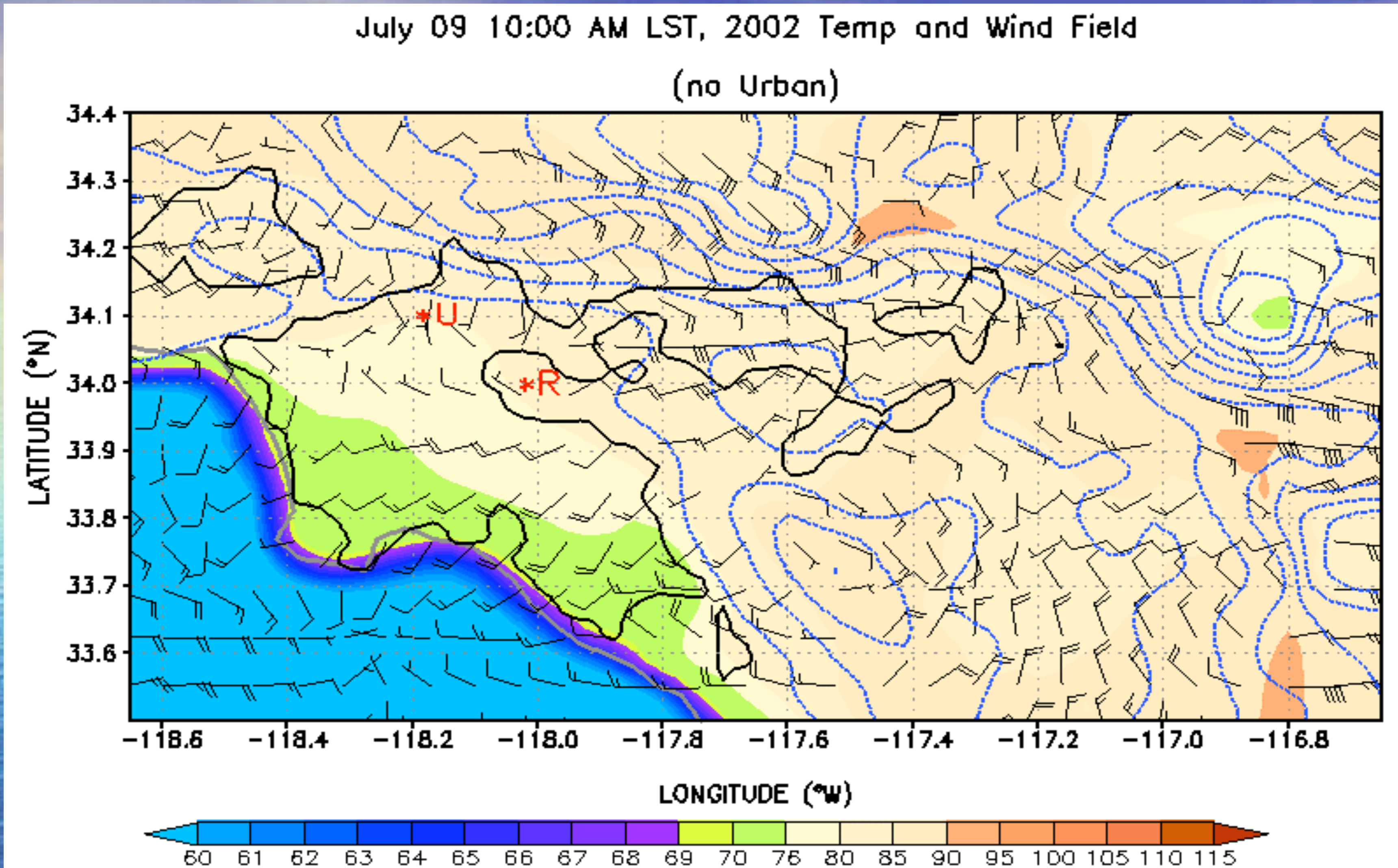
19-m RAMS spatial-patterns

- July day with max UHI
- Times shown
  - of nighttime max UHI (5 PM)
  - of daytime min UHI (10 AM)
- Temp and wind results from
  - Run 1: current urbanization
  - Run 2: no-urbanization
  - Run 1 minus Run 2

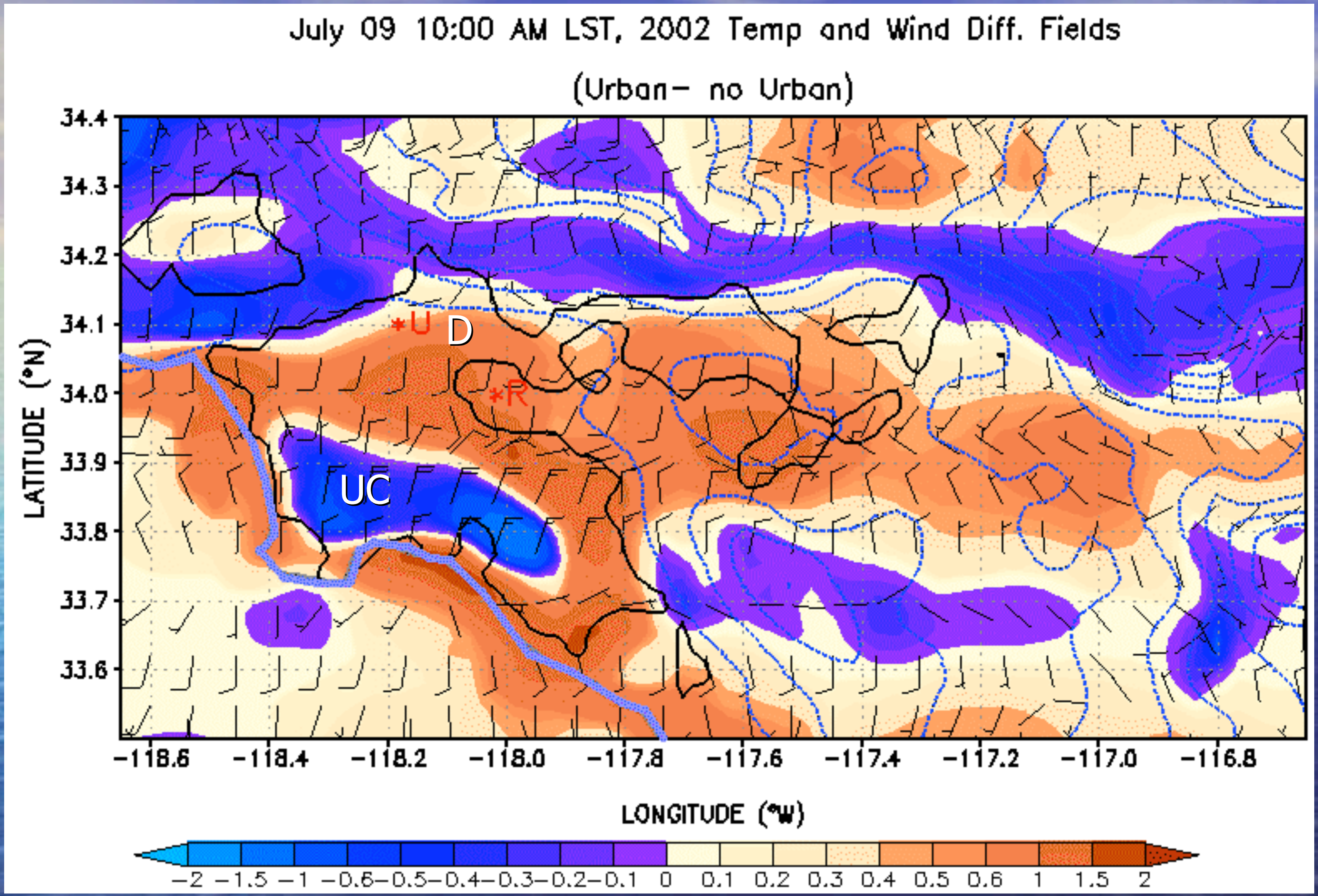


Run-1, 10 AM Key: Meso barbs=1 m/s; bold gray line=coast line; dotted light-blue line= topography; colors= temperature; dashed black line=observational analysis domain; solid black line=outline of city;*U=urban, *R =rural sites for above UHI calculation Rural results: off-shore div-zone, div (D) due to start of upslope vs. nocturnal offshore; start of sea breeze; mt.-top con due to start of up-slope flows (M)

Urban results: UCI (green area) and no initiation of a sea breeze due to urban roughness



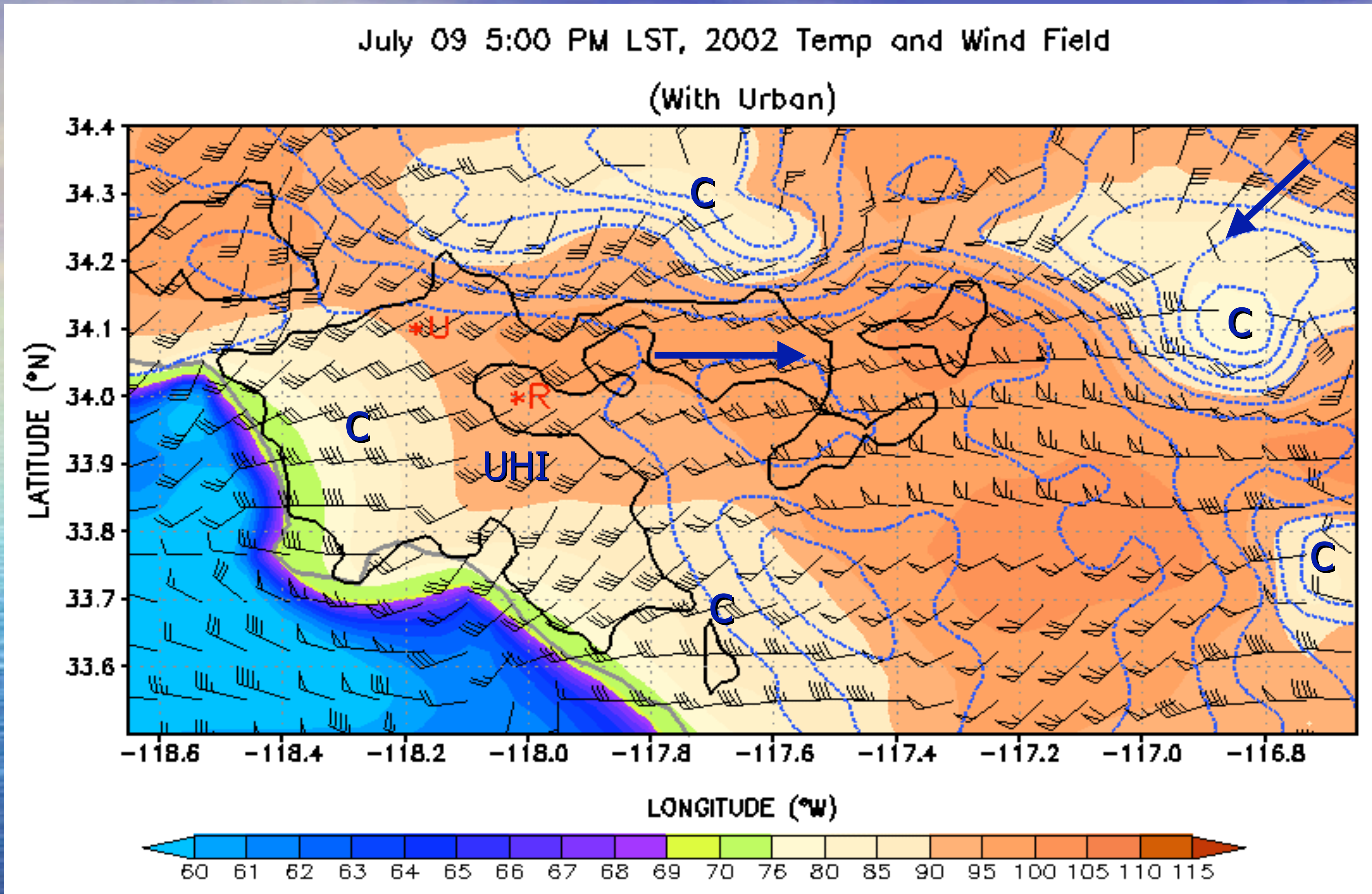
Run 2 (no urban): same key; next slide shows differences



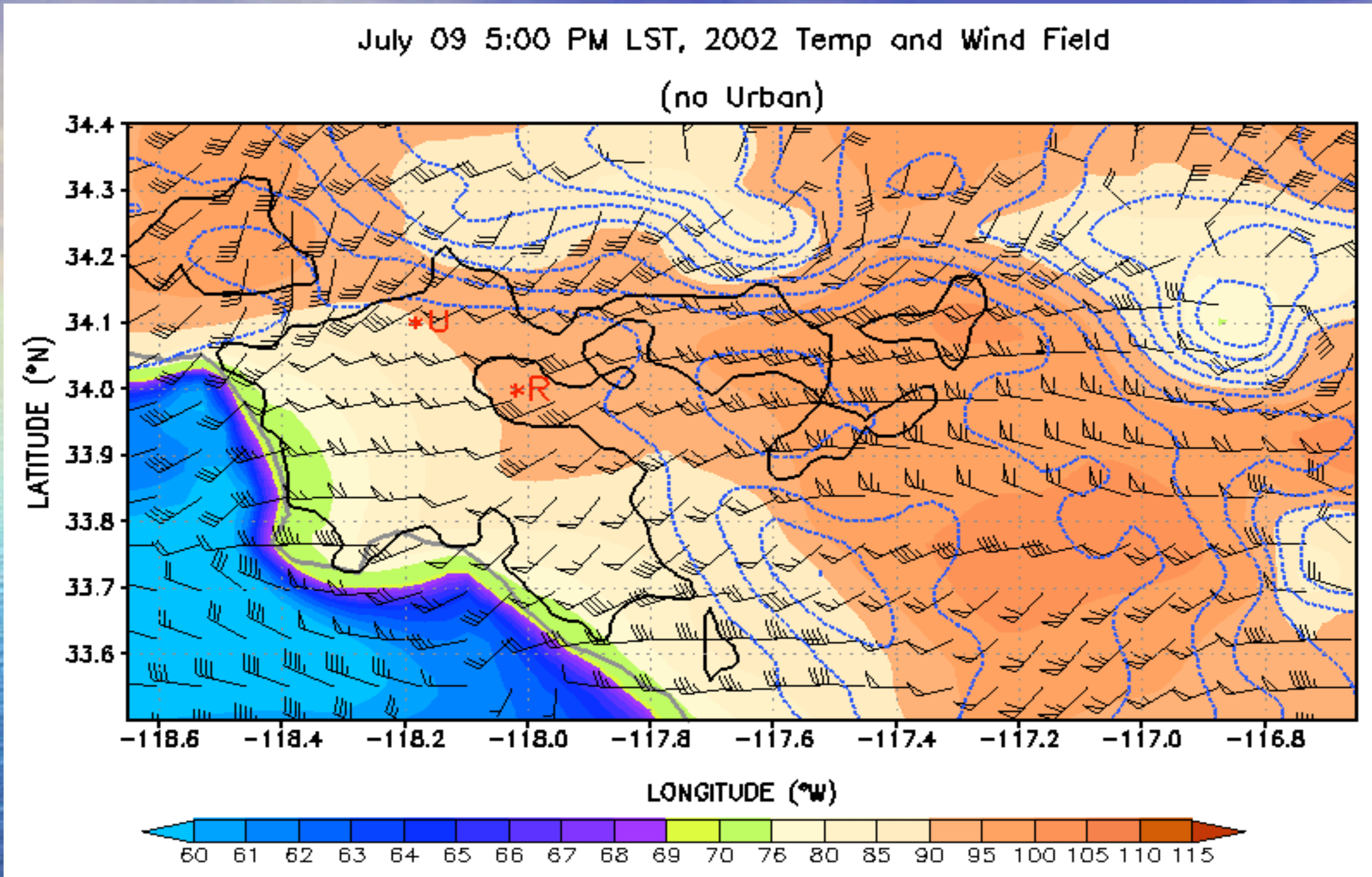
Run 1 minus Run 2, 10 AM key:

Urban: urban has cooled (UC) and has a counter-flow (Run-1 vector is onshore & difference vector is offshore due to z_0-deceleration)

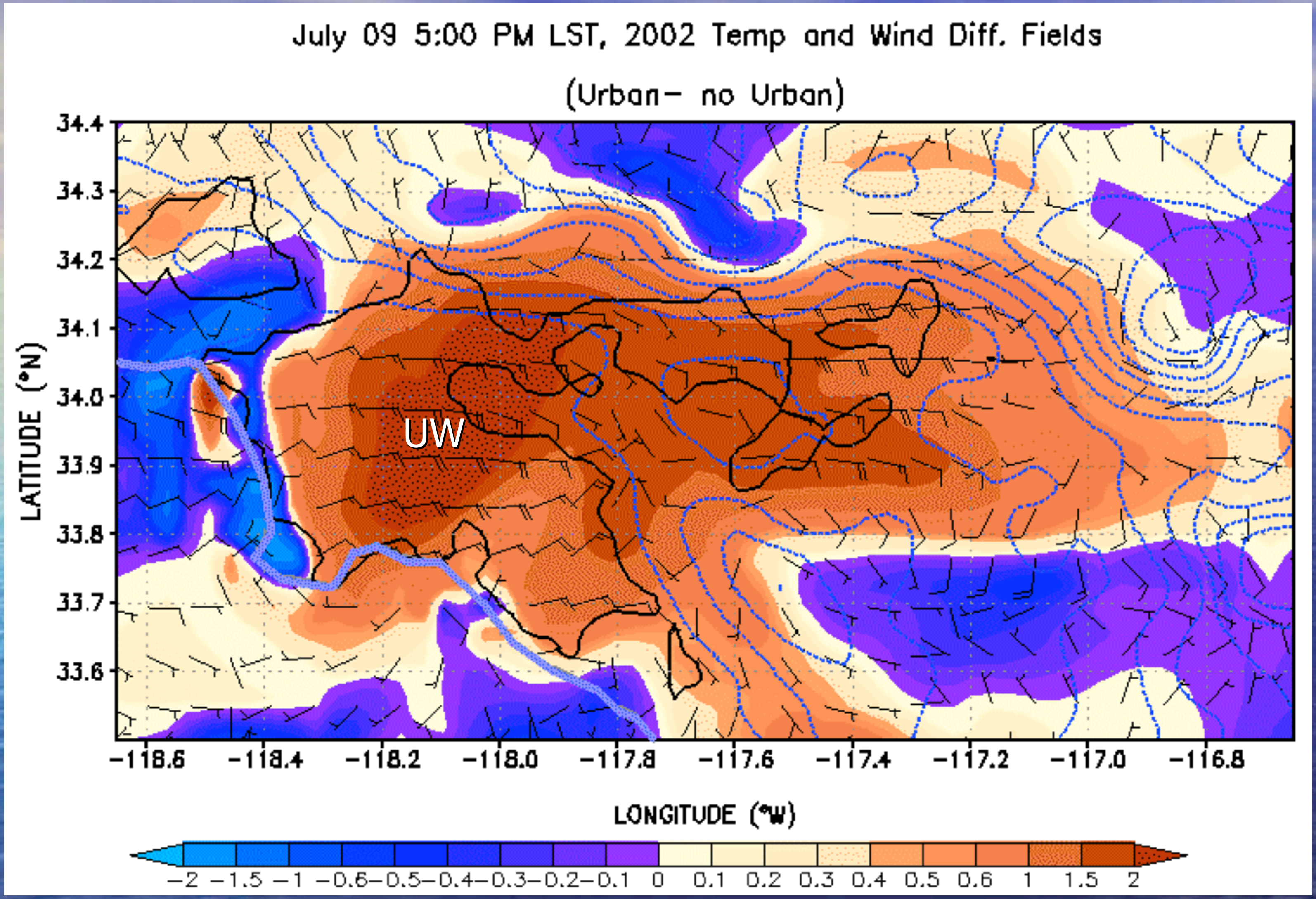
Rural: low elevation has warmed due to subsidence warming from div; slopes are cooling to induced secondary-circulations



Run-1, 5 PM Key: same, except dotted line is plane of next cross section
Rural results: (a) cool (C): coastal strip & mt. tops (b) linked sea-breeze & upslope flows
Urban results: UHI & roughness-retarded sea-breeze speeds



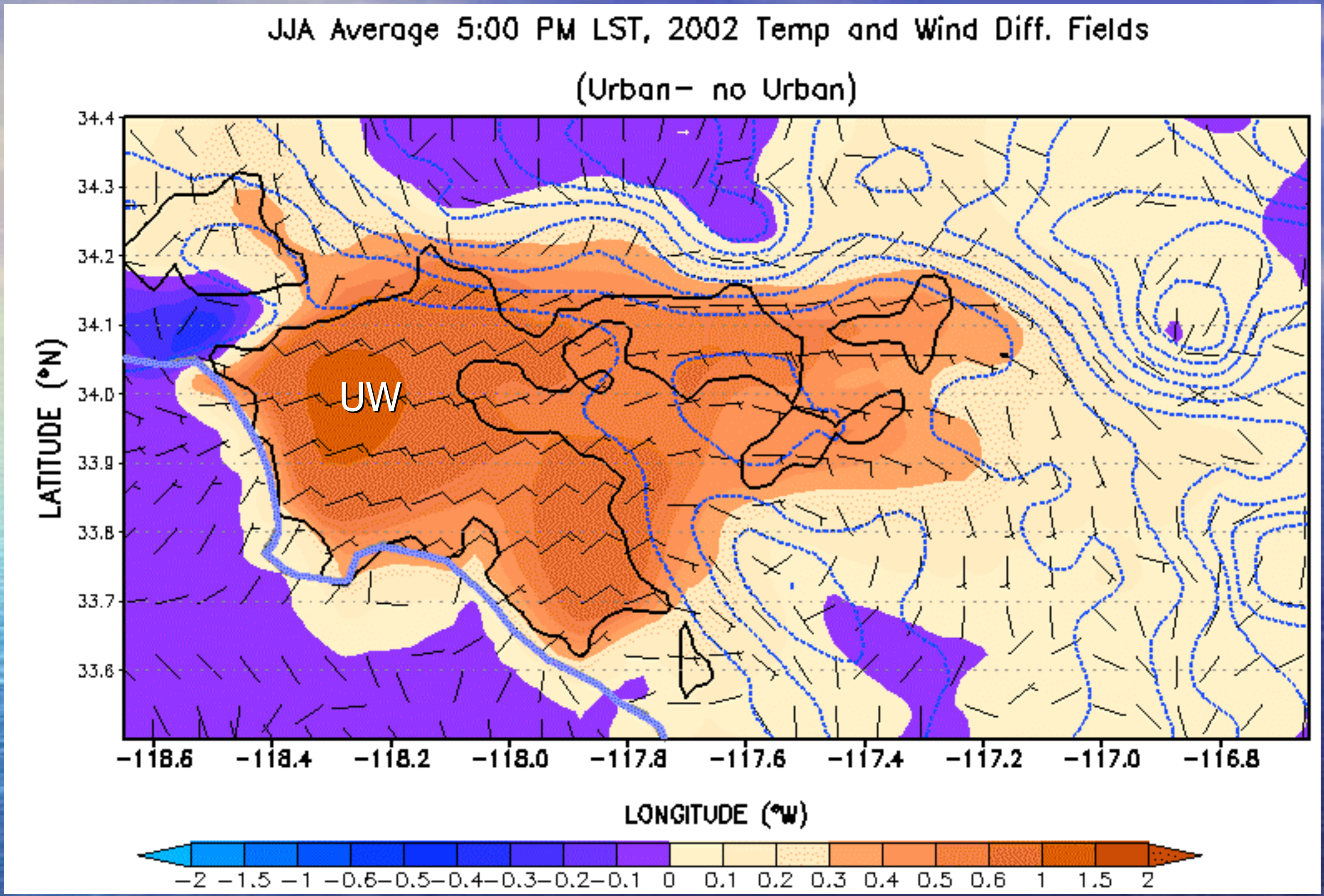
Run 2 (no urban): same key; next slide shows differences



Run 1 minus Run 2, 5 PM key:

Urban: urban has large warming (UW) area and counter-flow (Run-1 vector is onshore & difference vector is offshore due to z_0-deceleration)

Rural: low elevation has smaller warming due to adv; interior has cooled due to induced secondary-circulations

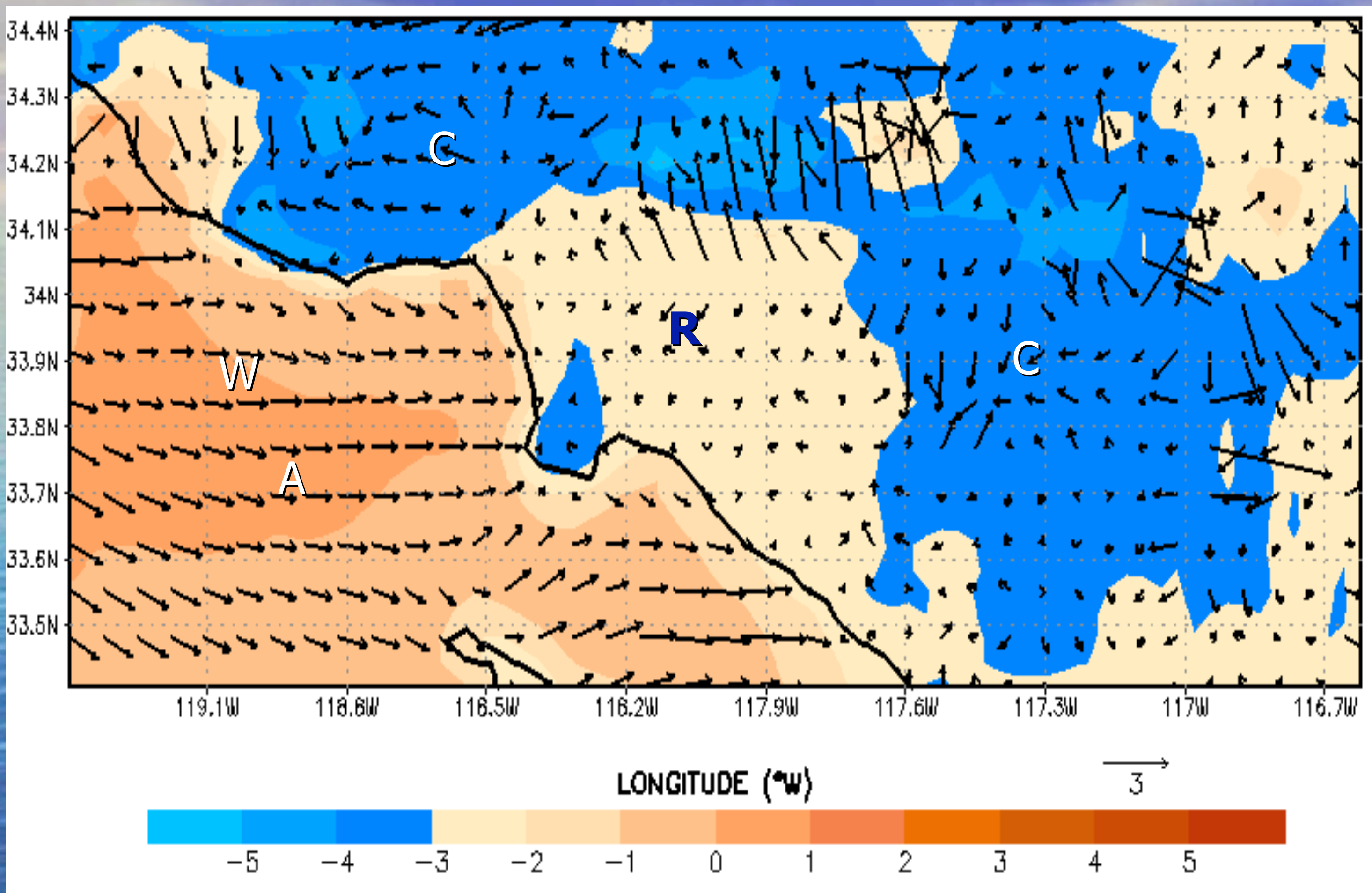


Run 1 minus Run 2, 5 PM key: same as previous slide, but for JJA

Urban: urban has large warming (UW) area and counter-flow (Run-1 vector is onshore & difference vector is offshore due to z0-deceleration)

Rural: low elevation has smaller warming due to adv; interior has cooled due to induced secondary-circulations

5 PM Aug 1-10 average change (current-2002 minus past-1970): temp (colors) and speed vectors (m/s)



Temps: GHG warming (W) over Ocean (2 K) increases sea breeze flow (2-3 m/s), which cools (C) temps over rural area (3-4 K), while the UHI counters this sea breeze induced-cooling (as city only cools by 2-3 K).
Winds: Stronger HPGF accelerates (A) over-ocean flow (by 2 m/s), but urban z_0 retards (R) on-shore flow over the city by 1 m/s

Summary

- The effects of urbanization & GHG changes in SoCAB were studied with the RAMS meso-met model
- Urbanization produces

  > 5 PM: increased UHIs & slowing of sea breeze penetration (due to large urban z_0)

  > 10 AM: urban cooling & slowing of sea breeze speeds (due to large urban z_0)
- Increased GHGs from 1970 to 2002 resulted in

  > increased sea breeze over ocean, and thus

  > an sea-breeze induced coastal-cooling, except in urban areas where

  >> the UHI partially countered this sea breeze induced-cooling

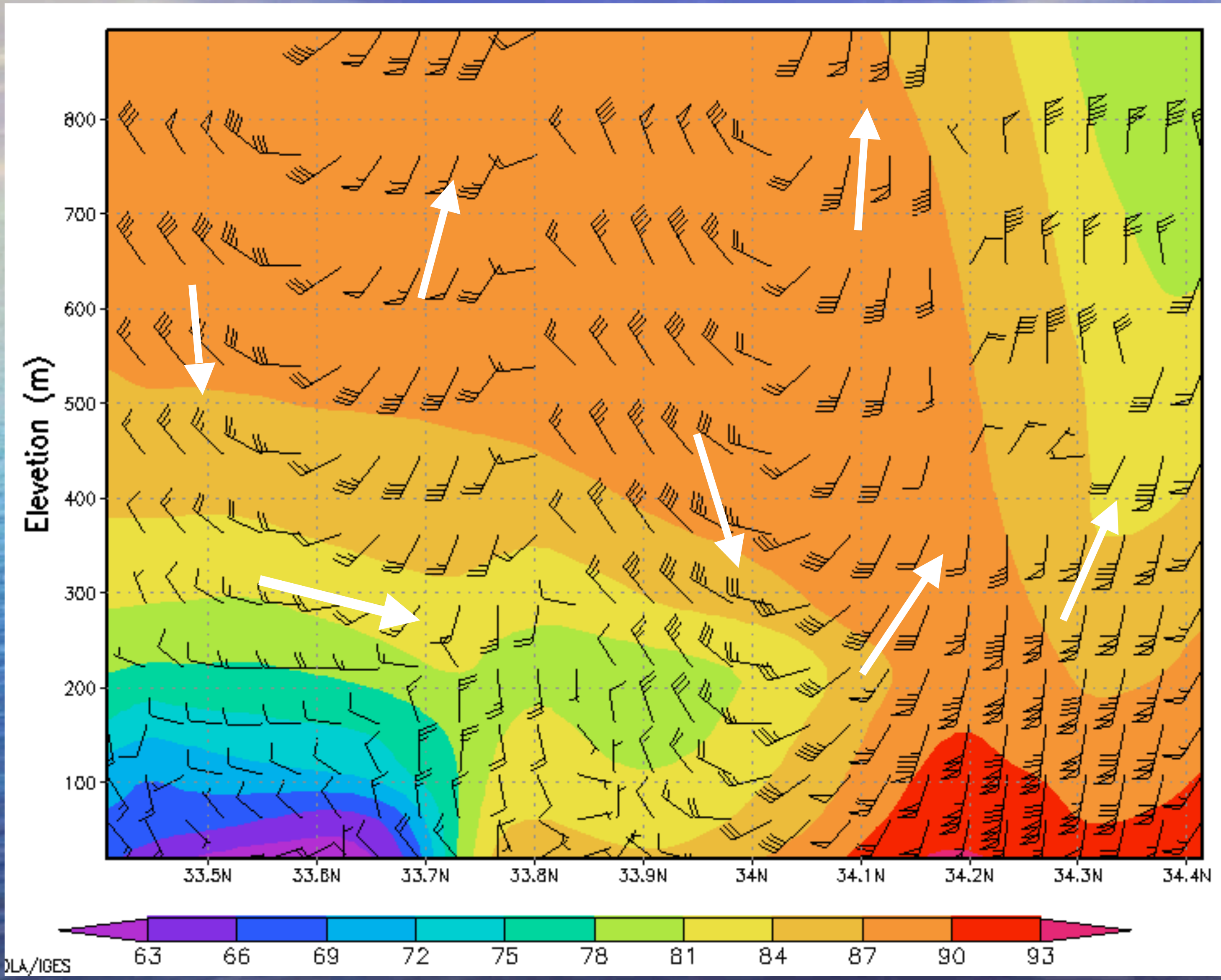
  >> urban z_0 retarded the on-shore flow over the city
- Future efforts will include

  > simulation of JJA past- & present-climate and LULC-change scenarios

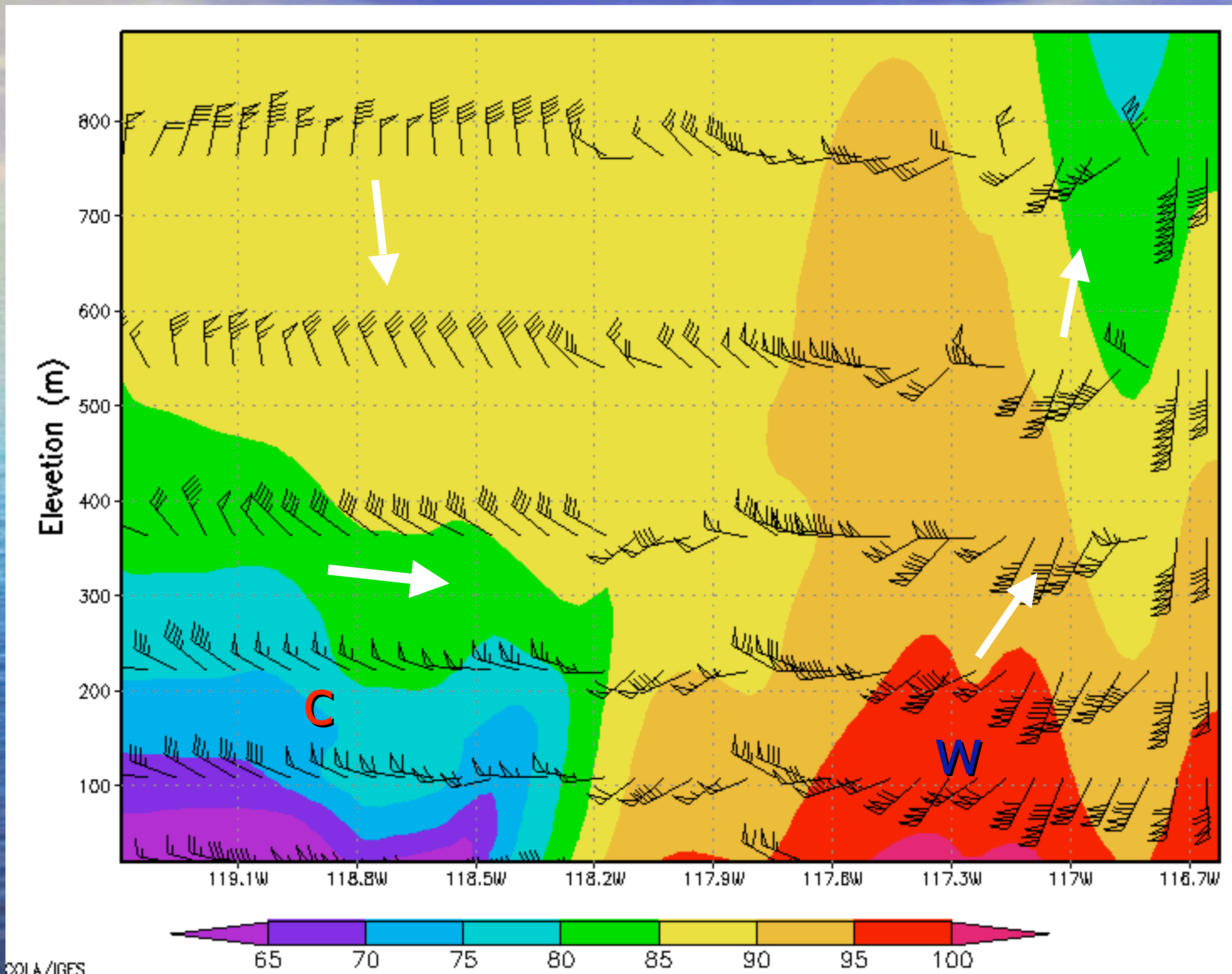
  > quantification of JJA coastal-cooling and inland-warming rates

Thank You!

July 09 5:00 PM LST Vertical Prof. Sliced at 118.25 ^oW



9 July, 5 PM LST: u, 100-w as f(x, z) at 34°N



TAVE:
INCREASED A MEDIUM RATE
(b) TMIN
INCREASED THE FASTEST
(c) TMAX
INCREASED AT THE SLOWEST RATE
(d) DTR
DCREASED
SLOW TRENDS b/n 1950 and 1970